GEOLOGIC ATLAS OF THE
UNITED STATES

HARPERS FERRY FOLIO,
VIRGINIA-MARYLAND-WEST VIRGINIA

COPY 2

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J.W. POWELL, DIRECTOR

GEOLOGIC ATLAS

OF THE

UNITED STATES

HARPERS FERRY FOLIO

VIRGINIA - MARYLAND - WEST VIRGINIA

INDEX MAP

SCALE: 40 MILES = 1 INCH

AREA OF THE HARPERS FERRY FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION   TOPOGRAPHY   AREAL GEOLOGY   ECONOMIC GEOLOGY   STRUCTURE SECTIONS

FOLIO 10   LIBRARY EDITION   HARPERS FERRY

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS   S. J. KÜBEL, CHIEF ENGRAVER

1894

EXPLANATION.

The Geological Survey is making a large topographic map and a large geologic map of the United States, which are being issued together in the form of a Geologic Atlas. The parts of the atlas are called folios. Each folio contains a topographic map and a geologic map of a small section of country, and is accompanied by explanatory and descriptive texts. The complete atlas will comprise several thousand folios.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, prairies, valleys, hills and mountains; (2) distribution of water, called *drainage*, as streams, ponds, lakes, swamps and canals; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined and those which are most important are stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

The manner in which contours express the three conditions of relief (elevation, horizontal form and degree of slope) is shown in the following sketch and corresponding contour map:

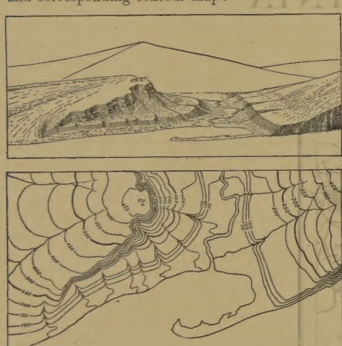


Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate height, form and slope:

1. A contour indicates approximately a height above sea level. In this illustration the contour interval is 50 feet; therefore the contours occur at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and so on with any other contour. In the space between any two contours occur all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours are made heavy and are numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the horizontal forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines and define all prominences. The relations of contour characters to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope. Therefore contours are far apart on the gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is chosen; for a steep or mountainous country a large contour interval is necessary. The smallest contour interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for districts like the Mississippi delta and the Dismal Swamp region. In mapping great mountain masses like those in Colorado, on a scale of $\frac{1}{250,000}$, the contour interval may be 250 feet. For intermediate relief other contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—The water courses are indicated by blue lines, which are drawn unbroken where the stream flows the year round, and dotted where the channel is dry a part of the year. Where the stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Marshes and canals are also shown in blue.

Culture.—In the progress of the settlement of any region men establish many artificial features. These, such as roads, railroads and towns, together with names of natural and artificial details and boundaries of towns, counties and states, are printed in black.

As a region develops, culture changes and gradually comes to disagree with the map; hence the representation of culture needs to be revised from time to time. Each sheet bears on its margin the dates of survey and of revision.

Scales.—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "one mile to one inch" is expressed by $\frac{1}{63,360}$.

Three different scales are used on the atlas sheets of the U. S. Geological Survey; the smallest is $\frac{1}{250,000}$, the second $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to four miles two miles, and one mile of natural length to one inch of map length. On the scale $\frac{1}{62,500}$ one square inch of map surface represents and corresponds nearly to one square mile; on the scale of $\frac{1}{125,000}$, to about four square miles; and on the scale of $\frac{1}{250,000}$ to about sixteen square miles. At the bottom of each atlas sheet the scale is expressed as a fraction, and it is further indicated by a "bar scale," a line divided into parts representing miles and parts of miles.

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree These areas correspond nearly to 4000, 1000 and 250 square miles.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the states, counties or townships. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

THE GEOLOGIC MAP.

A geologic map represents the distribution of rocks, and is based on a topographic map,—that is, to the topographic representation the geologic representation is added.

Rocks are of many kinds in origin, but they may be classed in four great groups: Superficial Rocks, Sedimentary Rocks, Igneous Rocks and Altered Rocks. The different kinds found within the area represented by a map are shown by devices printed in colors.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. The materials composing them likewise vary with locality, for the conditions of their deposition at different times and places have not been alike, and accordingly the rocks show many variations. Where beds of sand were buried beneath beds of mud, sandstone may now occur under shale; where a flow of lava cooled and was overflowed by another bed of lava, the two may be distinguished. Each of these masses is limited in extent to the area over which it was deposited, and is bounded above and below by different rocks. It is convenient in geology to call such a mass a *formation*.

(1) *Superficial rocks.*—These are composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated.

Within a recent period of the earth's history, a thick and extensive ice sheet covered the northern portion of the United States and part of British America, as one now covers Greenland. The ice gathered slowly, moved forward and retreated as glaciers do with changes of climate, and after a long and varied existence melted away. The ice left peculiar heaps and ridges of gravel; it spread layers of sand and clay, and the water flowing from it distributed sediments of various kinds far and wide. These deposits from ice and flood, together with those made by water and winds on the land and shore after the glacier had melted, and those made by similar agencies where the ice sheet did not extend, are the superficial formations. This period of the earth's history, from the beginning of the glacial epoch to the present, is called the Pleistocene period.

The distribution of the superficial rocks is shown on the map by colors printed in patterns of dots and circles.

(2) *Sedimentary rocks.*—These are conglomerate, sandstone, shale and limestone, which have been deposited beneath seas or other large bodies of water and have usually become hard.

If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes. The Appalachian mountains would become an archipelago in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses; and as it rises or subsides the shore lines of the oceans are changed.

The bottom of the sea is made of gravel, sand and mud, which are sorted and spread. As these sediments gather they bury others already deposited and the latter harden into layers of conglomerate, sandstone, shale or limestone. When the sea bottom is raised to dry land these rocks are exposed, and then we may learn from them many facts concerning the geography of the past.

As sedimentary strata accumulate the younger beds rest on those that are older and the relative ages of the deposits may be discovered by observing their relative positions. In any series of undisturbed beds the younger bed is above the older.

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found.

Beds of rock do not always occur in the positions in which they were formed. When they have been disturbed it is often difficult to determine their relative ages from their positions; then fossils are a guide to show which of two or more formations is the oldest. When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which one was formed first. Fossil remains found in the rocks of different states, of different countries and of different continents afford the most important means for combining local histories into a general earth history.

Areas of sedimentary rocks are shown on the map by colors printed in patterns of parallel straight lines. To show the relative age of strata on the map, the history of the sedimentary rocks is divided into nine periods, to each of which a color is assigned. Each period is further distinguished by a letter-symbol, so that the areas may be known when the colors, on account of fading, color blindness or other cause, cannot be recognized. The names of the periods in proper order (from new to old), with the color and symbol assigned to each, are given below:

PERIOD.	SYMBOL.	COLOR—PRINTED IN PATTERNS OF PARALLEL LINES.
Neocene (youngest).	N	Yellowish buff.
Eocene	E	Olive-brown.
Cretaceous	K	Olive-green.
Juratrias	J	Gray-blue-green.
Carboniferous	C	Gray-blue.
Devonian	D	Gray-blue-purple.
Silurian	S	Gray-red-purple.
Cambrian	Є	Brown-red.
Algonkian (oldest) .	A	Orange-brown.

In any district several periods may be represented, and the representation of each may include one or many formations. To distinguish the sedimentary formations of any one period from those of another, the patterns for the formations of each period are printed in the appropriate period-color; and the formations of any one period are distinguished from one another by different patterns. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

(3) *Igneous rocks.*—These are crystalline rocks, which have cooled from a molten condition.

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they

DESCRIPTION OF THE HARPERS FERRY SHEET.

GEOGRAPHY.

General relations.—The region represented by the Harpers Ferry atlas sheet lies chiefly in Virginia, but includes also portions of West Virginia and Maryland.

In its geographic and geologic relations this area forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west, and from central Alabama to southern New York. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as that covered by a single atlas sheet; hence it is necessary to consider the individual sheet in its relations to the entire province.

Subdivisions of the Appalachian province.—The Appalachian province may be subdivided into three well-marked physiographic divisions, throughout each of which certain forces have produced similar results in sedimentation, in geologic structure, and in topography. These divisions extend the entire length of the province, from northeast to southwest.

The central division is the Appalachian Valley. It is the best defined and most uniform of the three. In the southern part it coincides with the belt of folded rocks which forms the Coosa Valley of Georgia and Alabama and the Great Valley of East Tennessee and Virginia. Throughout the central and northern portions the eastern side only is marked by great valleys—such as the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and Pennsylvania, and the Lebanon Valley of northeastern Pennsylvania—the western side being a succession of ridges alternating with narrow valleys. This division varies in width from 40 to 125 miles. It is sharply outlined on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the Alleghany Mountains. Its rocks are almost wholly sedimentary and in large measure calcareous. The strata, which must originally have been nearly horizontal, now intersect the surface at various angles and in narrow belts. The surface differs with the outcrop of different kinds of rock, so that sharp ridges and narrow valleys of great length follow the narrow belts of hard and soft rock. Owing to the large amount of calcareous rock brought up on the steep folds of this district its surface is more readily worn down by streams and is lower and less broken than the divisions on either side.

The eastern division of the province embraces the Appalachian Mountains, a system which is made up of many minor ranges and which, under various local names, extends from southern New York to central Alabama. Some of its prominent parts are the South Mountain of Pennsylvania, the Blue Ridge and Catoctin Mountain of Maryland and Virginia, the Great Smoky Mountains of Tennessee and North Carolina, and the Cohutta Mountains of Georgia. Many of the rocks of this division are more or less crystalline, being either sediments which have been changed to slates and schists by varying degrees of metamorphism, or igneous rocks, such as granite and diabase, which have solidified from a molten condition.

The western division of the Appalachian province embraces the Cumberland Plateau and the Alleghany Mountains and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the Mississippi River as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian Valley by the Alleghany front and the Cumberland escarpment. The rocks of this division are almost entirely of sedimentary origin and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely worn down. In the southern half of the province the plateau is sometimes extensive and perfectly flat, but it is oftener much divided by streams into large or small areas with flat tops. In West Virginia and portions of Pennsylvania the plateau is sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion, and the surface is now comparatively low and level, or rolling.

Altitude of the Appalachian province.—The Appalachian province as a whole is broadly dome-shaped, its surface rising from an altitude of about 500 feet along the eastern margin to the crest of the Appalachian Mountains, and thence descending westward to about the same altitude on the Ohio and Mississippi rivers.

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1,000 feet in Alabama to more than 6,600 feet in western North Carolina. From this culminating point they decrease to 4,000 or 3,000 feet in southern Virginia, rise to 4,000 feet in central Virginia, and descend to 2,000 or 1,500 feet on the Maryland-Pennsylvania line.

The Appalachian Valley shows a uniform increase in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2,000 feet at the Tennessee-Virginia line, and 2,600 or 2,700 feet at its culminating point, on the divide between the New and Tennessee rivers. From this point it descends to 2,200 feet in the valley of New River, 1,500 to 1,000 feet in the James River basin, and 1,000 to 500 feet in the Potomac basin, remaining about the same through Pennsylvania. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2,000 feet.

The plateau, or western, division increases in altitude from 500 feet at the southern edge of the province to 1,500 feet in northern Alabama, 2,000 feet in central Tennessee, and 3,500 feet in southeastern Kentucky. It is between 3,000 and 4,000 feet in West Virginia, and decreases to about 2,000 feet in Pennsylvania. From its greatest altitude, along the eastern edge, the plateau slopes gradually westward, although it is generally separated from the interior lowlands by an abrupt escarpment.

Drainage of the Appalachian province.—The drainage of the province is in part eastward into the Atlantic, in part southward into the Gulf, and in part westward into the Mississippi. All of the western, or plateau, division of the province, except a small portion in Pennsylvania and another in Alabama, is drained by streams flowing westward to the Ohio. The northern portion of the eastern, or Appalachian Mountain, division is drained eastward to the Atlantic, while south of the New River all except the eastern slope is drained westward by tributaries of the Tennessee or southward by tributaries of the Coosa.

The position of the streams in the Appalachian Valley is dependent upon the geologic structure. In general they flow in courses which for long distances are parallel to the sides of the Great Valley, following the lesser valleys along the outcrops of the softer rocks. These longitudinal streams empty into a number of larger, transverse rivers, which cross one or the other of the barriers limiting the valley. In the northern portion of the province they form the Delaware, Susquehanna, Potomac, James, and Roanoke rivers, each of which passes through the Appalachian Mountains in a narrow gap and flows eastward to the sea. In the central portion of the province, in Kentucky and Virginia, these longitudinal streams form the New (or Kanawha) River, which flows westward in a deep, narrow gorge through the Cumberland Plateau into the Ohio River. From New River southward to northern Georgia the Great Valley is drained by tributaries of the Tennessee River, which at Chattanooga leaves the broad valley and, entering a gorge through the plateau, runs westward to the Ohio. South of Chattanooga the streams flow directly to the Gulf of Mexico.

Geographic divisions of the Harpers Ferry area.—In the area of this atlas sheet there are three geographic divisions, of widely different aspect: the Shenandoah Valley, the mountain belt bordered by Blue Ridge and Catoctin Mountain, and the upland plain east of Catoctin Mountain. The entire region is drained by the Potomac River and its tributaries. The most important of these are Shenandoah River and Goose Creek. Other considerable streams are Antietam Creek, Opequon Creek, and the two Catoctin creeks.

The mountain district is composed of three members: Catoctin Mountain on the east, Blue Ridge and South Mountain on the west, and an intermediate valley. Catoctin Mountain extends in a continuous line through the area of the sheet and passes into Pennsylvania. Southward through Virginia its line is directly continued by Bull Run Mountain for 15 miles. Blue Ridge is continuous through Virginia to its end in Maryland. Near the Potomac, South Mountain begins, lapping past the Blue Ridge and continuing the line of elevation far into Pennsylvania.

To an observer looking across the Shenandoah Valley or the valley between Blue Ridge and Catoctin Mountain the surface appears nearly level at an altitude of 500 feet. In many regions at a distance from the large streams this is really the case. Traversing this level in most places, however, are narrow, abrupt valleys, occupied by the larger streams, which are not noticeable until near at hand. These small valleys deepen as the streams increase in size, and the largest creeks and the rivers are from 200 to 250 feet below the general level of the country.

A plain similar to this in origin lies along the eastern side of Catoctin Mountain at an elevation of 350 feet. In the summits of the mountains other plains can be discovered, which originally were continuous at the same height across the intervening valleys. These are obscure, however, and have been almost totally worn away during the formation of the later and lower peneplains.

The nature of these three geographic districts is directly dependent on the rocks composing their surfaces. The rocks differ greatly in composition, and as they resist the wear of streams and the decay of weather in different degrees, so the surface which they form varies. The Shenandoah Valley is underlain by the Shenandoah limestones and the Martinsburg shales. The calcareous matter in them is readily dissolved, and the surface is therefore low and smoothly rounded. The upland plain east of Catoctin Mountain is underlain by the Newark red sandstone and conglomerate, which also contain much soluble matter and are therefore worn down to low, rounded surfaces similar to those of the Shenandoah Valley. The mountain district is underlain by many kinds of rock, chiefly granite, schist, shale, slate, sandstone, and conglomerate. None of these rocks contain much soluble matter, compared with those of the other districts, and accordingly this district has more varied forms and steeper slopes. The granite, slate, and shale offer the least resistance to erosion, because they contain considerable feldspar, which decays readily; accordingly, they form the low areas of the mountain district. The Weverton sandstone and most of the Catoctin schist are little affected by decay, and form the high ground of Catoctin and South mountains and Blue Ridge. Portions of the schist associated with the granite are more easily decayed, and occupy low ground with the granite. The surfaces produced by all these rocks are smooth and susceptible of cultivation, except that of the Weverton sandstone, which invariably makes rough, rocky ridges, with frequent cliffs and bowlders. Some of the schist surfaces are encumbered with loose masses of epidote weathered from the rock, but cliffs are rare and highlands are broad, soil-covered domes.

GEOLOGY.

STRATIGRAPHY.

The general sedimentary record.—Most of the rocks appearing at the surface within the limits of the Harpers Ferry atlas sheet are of sedimentary origin—that is, they were deposited by water. They consist of sandstone, shale, and limestone, all presenting great variety in composition and appearance. The materials of which they are composed were originally gravel, sand, and mud, derived from the waste of older rocks, and the remains of plants and animals which lived while the strata were being laid down. Thus some of the great beds of limestone were formed largely from the shells of various sea animals, and the beds of coal are the remains of a luxuriant vegetation, which probably covered low, swampy shores.

Other rocks occurring in this region—those of igneous origin—were formed at two widely separated periods. They were poured forth on the surface and forced into other formations in Algonkian time and again in the Juratrias period.

The rocks afford a record of sedimentation from earliest Cambrian to Juratrias time. Their composition and appearance indicate at what distance from shore and in what depth of water they were deposited. Sandstones marked by ripples and cross-bedded by currents, and shales cracked by drying on mud flats, indicate shallow water; while limestones, especially by the fossils they contain, indicate greater depth of water and scarcity of sediment. The character of the adjacent land is shown by the character of the sediments derived from its waste. Coarse sandstones and conglomerates, such as are found in the Coal Measures, were derived from high land on which stream grades were steep, or they may have resulted from wave action as the sea encroached upon a sinking coast. Red sandstones and shales, such as make up some of the Cambrian and Silurian formations, result from the revival of erosion on a land surface long exposed to rock decay and oxidation, and hence covered by a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low and that its streams were too sluggish to carry off coarse sediment, the sea receiving only fine sediment and substances in solution.

The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin. The area of the Harpers Ferry sheet was near its eastern margin, and the materials of which its rocks are composed were therefore derived largely from the land to the east. The exact position of the eastern shoreline of this ancient sea is not known, but it probably varied from time to time within rather wide limits.

Three great cycles of sedimentation are recorded in the rocks of this region. Beginning with the first definite record, coarse sandstones and shales were deposited in early Cambrian time along the eastern border of the interior sea as it encroached upon the land. As the land was worn down and still further depressed, the sediment became finer, until in the Knox dolomite of the Cambro-Silurian period very little trace of shore material is seen. Following this long period of quiet was a slight elevation, producing coarser rocks; this became more and more pronounced, until, between the lower and upper Silurian, the land was much expanded and large areas of recently deposited sandstones were lifted above the sea, thus completing the first great cycle. Following this elevation came a second depression, during which the land was again worn down nearly to baselevel, affording conditions for the accumulation of the Devonian black shale. After this the Devonian shales and sandstones were deposited in steadily increasing coarseness, recording the gradual uplift of the land. The third cycle began with a depression, during which the Carboniferous limestone accumulated, containing scarcely any shore waste. A third uplift brought the limestone into shallow water—portions of it perhaps above the sea—and upon it were deposited, in shallow water and swamps, the sandstones, shales, and coal beds of the Carboniferous. Finally, at the close of the Carboniferous, a further uplift ended the deposition of sediment in the Appalachian province, except along its borders in recent times. The columnar section shows the composition, name, age, and thickness of each.

In location the rocks are gathered into distinct groups which follow very closely the three great topographic districts. The Shenandoah Valley is composed almost entirely of the Shenandoah (Siluro-Cambrian) limestone, with one belt of Martinsburg shale. The district east of Catoctin Mountain is underlain by Newark sandstone, shale, conglomerate, and diabase. The mountain district is more varied in its geology, as it is in its topography, the latter being directly

dependent on the former. In a general way the older rocks appear in the middle of the district and the younger rocks on its borders. The central valley is underlain by Catoctin schist and granite. The mountains are formed of Weverton sandstone and the epidotic Catoctin schist. Over the surface of the central valley occur many narrow belts of Loudoun slate and sandstone.

IGNEOUS ROCKS.

ALGONKIAN PERIOD.

Quartz-porphyry.—This rock occurs in only two places in the Harpers Ferry area, and neither outcrop is of sufficient size to show upon the map. One locality is immediately north of Rohrersville, Maryland; the other is 1 mile west of Oatlands, Virginia. Its general composition is as follows: silica, 74 per cent; alumina, 12 per cent; and iron oxides, 6 per cent. The rock is composed of crystals of feldspar and quartz scattered through an extremely fine groundmass of the same minerals. In both of these areas the rock has been much squeezed, altering the feldspar crystals into parallel flakes of quartz and muscovite to such an extent as to destroy most of the original character of the rock and to produce a schist much like some of the Loudoun slates.

Andesite.—This rock is even more rare in this region than the quartz-porphyry, being confined to a few doubtful outcrops along the east side of the Blue Ridge, which are too small to be shown on the map. Its chief chemical constituents are: silica, 51 per cent; alumina, 11 per cent; iron oxides, 17 per cent; lime, magnesia, and soda, 15 per cent. The rock consists of fine grains of quartz, sharp feldspar crystals, minute grains of magnetite and ilmenite, and a little epidote. Occasionally the quartz and epidote are gathered into small, rounded bunches, or amygdules. The general color of the rock is a dark bluish-gray, and the grain is always too fine to show the individual crystals except in the amygdules. In the regions where its character is more apparent this rock has been determined to have been a volcanic lava flow.

Catoctin schist.—The Catoctin schist is more extensive in this region than any other rock except the Shenandoah limestone. It is so named on account of its great development in Catoctin Mountain. Its chief constituents are as follows: silica, 41 per cent; alumina, 18 per cent; iron oxides, 18 per cent; lime and magnesia, 14 per cent. The rock varies little in appearance: when fresh it is light bluish-green; when weathered it becomes dull grayish-yellow. The schist was originally a diabase or volcanic rock composed of crystals of feldspar, pyroxene, olivine, magnetite, and ilmenite. The original massive rock was altered by the tremendous pressure and distortion which accompanied folding, so that the pyroxene became chlorite, magnetite, and quartz, and the feldspar was crushed and partly altered to quartz, chlorite, and muscovite. The new minerals were arranged parallel to one another and thus became a "schist," characterized by the ease of splitting along these minerals. The amount of alteration increases from Blue Ridge to Catoctin Mountain.

The diabase from which the schist was produced was a flow of lava along the surface. It is probable that there were several eruptions, of somewhat different character, resulting in the different schists which are now found. Such distinct eruptions, however, can not be proved by the facts discoverable in this area.

Three varieties of schist can be distinguished: one of coarser texture, associated with the granite; one of fine grain, with large lenses of epidote and quartz, causing the mountains; and one with quartz and epidote amygdules, occurring along the boundaries of the other two varieties. The amygdaloidal variety is not sufficiently distinct or regular to be demarcated on the map; the epidotic variety is separately shown; the coarser schist is indicated with the granite areas, the two being too closely and universally interbedded for separate representation. The amygdaloidal cavities in the schist are usually filled with quartz and epidote, occasionally with feldspar, jasper, or calcite. They vary in size from one one-hundredth of an inch to one inch, with an average of about one-third of an inch. The minerals are arranged in most cases in concentric layers, but rarely they are developed in radiating bunches. If this rock were uniform in quality and quantity and were not so refractory as to be almost unworkable, its great beauty would make it a valuable ornamental stone.

The great lenses of quartz and epidote which mark one variety of the schist vary in size from minute grains up to masses 5 feet thick, the quartz bodies being hardly as large as the epidote. Both kinds are arranged parallel to the schistose planes and were produced at nearly the same time.

A residual red clay from the decay of the schist covers the decomposing rock to a considerable depth and forms a strong soil. Only in the recent stream cuts can the unweathered rock be found, and ledges of the schist itself are not common even on the mountains. The epidote and quartz, being insoluble, do not decay, and their masses have accumulated in many places so thickly as almost completely to cover the soil. Where the encumbrance of these blocks is not excessive, the fertility of the soil repays the labor of removing them. The richness of the soil is largely due to the potash and lime of the feldspar and epidote. Its looseness is secured by the quartz and mica particles, and its drainage is usually good, as it lies on the steep slopes of the mountains and the hills of the peneplain.

Granite.—Granite is very widely distributed in the mountain district, usually occurring in long belts from a yard to 6 miles wide. Its northern limit is in Maryland, 10 miles north of the Potomac; thence southward its outcrops increase in extent and number.

The minerals composing the granite are chiefly quartz and orthoclase and plagioclase feldspar; besides these, biotite, garnet, epidote, and blue quartz occur, forming four types of granite in different areas. Occasionally magnetite and apatite also occur in small amount. The large proportion of quartz and feldspar in all the varieties makes the rock light-gray in color. Garnets are prominent in the granites near the Potomac on the west side of the mountain district, giving the rock a spotted appearance. Epidote occurs in the granite east of Rohrersville, Maryland, and west of Catoctin Mountain, near Goose Creek. Blue quartz is prominent in a belt running through Philomont and Lincoln, Virginia, and in a smaller area east of Milton, Virginia. This blue quartz, in addition to the white quartz, occurs in the form of irregular patches and veins, and its brilliant color makes it very noticeable. Biotite is present in most of the varieties of granite, but rarely in sufficient amount to affect the appearance of the rock.

The granite is wholly crystalline, and the individual minerals range in size from crystals which are scarcely visible up to those nearly an inch long. Areas of the coarser granite lie along the east side of the Blue Ridge and along the west side of Catoctin Mountain south of Goose Creek.

The granite has been extensively altered by pressure. The effect is most conspicuous on the east side of the mountain district, where the alteration can be traced through all stages from massive granite to granite reduced to slate and schist. The process of alteration consisted of fracture of the quartz and feldspar crystals by motion of one part of the rock over another. Together with this process a growth of muscovite and chlorite took place in the feldspar. According to the extent of the alteration the rock is a granite, a gneiss, or a quartz-schist, the last form being scarcely distinguishable from some of the Loudoun slates.

The granite is of eruptive nature; while fluid it was forced into fissures in the schist. This is apparent on a large scale in the long, narrow tongues of granite in the schist, and in the universal interbedding of the two rocks. At the contacts, also, it is plain in the alteration of the schist next to the granite, in the smaller crystals of the granite, due to sudden cooling, and in the fragments of schist included in the granite.

The granite decays readily on account of the large amount of feldspar that it contains, which is subject to solution. Many cases are found of granite decayed without change of form, so that it crumbles beneath the touch. The final product of decomposition is a deep, tenacious, red clay, with more or less fragmentary quartz scattered through it. As the proportion of quartz increases, the soil becomes looser and the color lighter. The lime and soda contained in the feldspar are of great value in making the soil of the granite productive, and the deepness of the soil and clay contributes to the same end. Good drainage and lightness are secured by the abundance of smaller quartz particles, the hilly condition of the peneplain also contributing to the same result.

JURATRIAS PERIOD.

Diabase.—This rock occurs in great abundance in the Newark strata south of Leesburg and in scattered dikes in the mountain district. It is an igneous rock, and was forced into fissures in the Newark strata in a molten condition. These fissures are very irregular in trend, sometimes following and sometimes crossing the beds of rock, and the thickness of eruptive material in them ranges from 10 feet to possibly 800 feet.

The diabase is wholly crystalline in texture and varies much in the size of its crystals. The coarse varieties are found in the larger bodies of diabase and have crystals one-third of an inch long; these bodies cooled slowly and the crystals had more time to grow. The fine varieties have no crystals visible to the eye, and occur in the small masses, which chilled and hardened rapidly.

The rock is composed of plagioclase feldspar, pyroxene, olivine, and magnetite, the two former being much the most prominent. To the large crystals of feldspar is due the gray color of the coarse diabase. In the finer grades the smaller feldspars are lost amid the darker minerals, and the color of the rock is dull greenish-black.

The sandstones and shales were altered by the heat of this rock when it was forced into the fissures. The sandstones near the diabase lost their ferruginous matter and were slightly silicified, with change of color to dull white. The shales were somewhat hardened and silicified, and developed a system of dark spots in a purplish base. At Leesburg, where the diabase touched the limestone conglomerate, the latter was partly recrystallized to marble.

Decay of the diabase appears to be rapid, yet countless bowlders of the solid rock are scattered over its areas. These are partly decayed, forming concentric shells, which peel off readily. Actual ledges are quite rare except near stream cuts, but nowhere is the covering of soil of great depth. Complete decay of the rock results in a stiff, brownish-yellow clay, which is almost impervious to moisture and air and protects the underlying rock. It is also a bar to good drainage, and the soils are cold and damp wherever the areas are at all flat. At its best the soil is poor, since the rock itself contains little potash but much soda and magnesia, and the cover of dense clay prevents communication with the decaying minerals of the rock below. Soils of the smaller dikes are modified and lightened by wash from the adjacent sandstones, and are fairly fertile.

SEDIMENTARY ROCKS.

CAMBRIAN PERIOD.

Loudoun formation.—This formation is in the main a fine, dark slate, but it comprises most varieties of sedimentary rocks, such as pure limestone, shale, sandstone, and coarse conglomerate. It is also extremely variable in thickness, ranging from 10 feet at Oatlands to 800 feet 4 miles west of that place. The coarser and thicker deposits are found in narrow synclines scattered over the granite and schist; the thinner and finer beds are in the synclines which contain the Weverton sandstone. Occasionally, as at Turners Gap, the formation is comparatively thick under the Weverton sandstone. It is so named because all its varieties are well displayed in Loudoun County, Virginia

The limestones occur in the form of lenses in the slate, and are developed along two lines, one being the axis of South Mountain, the other lying immediately west of Catoctin Mountain. Those of the eastern line are thicker and more continuous. Most of the outcrops have been worked for lime, but the chief value of the limestones lies in the beds of marble along the line of their eastern outcrops. The marbles are interbedded with slate and schist, sometimes in one bed, sometimes in two, but the beds are generally too small to work. At Goose Creek the marble bed is about 50 feet thick and has been opened to a considerable depth. The varieties there shown are chiefly white, but there occur also banded blue and white, serpentinized white and green, pink and white, and green and white. These beds are pure, and the stone is of great beauty and takes a good polish; thus far, however, the lack of transportion has prevented extensive quarrying. Farther south along its range the limestone is less metamorphosed into marble and increases in thickness.

Beds of sandstone are frequent in the Loudoun formation, especially in the southern and central portion of the mountain district. Between Oatlands and Philomont they are composed of fragments of granite washed together with little sorting or wear, and can hardly be distinguished from the parent granite. Three miles south of Philomont the formation contains beds of conglomerate. These are composed of angular fragments of blue and white quartz derived from the granite of neighboring areas and embedded in a fine matrix of mica flakes. Similar though finer conglomerates occur 3 miles northwest of Philomont and 1 mile southeast of Snickersville. Many beds of the formation contain grains of magnetite and ilmenite washed from the Catoctin schist. Coarser fragments of the schist, such as epidote and jasper, occur in the Loudoun slate 1 mile east of Harpers Ferry and half a mile south of Rohrersville, Maryland.

The Loudoun formation was the first sediment deposited upon the crystalline rocks, and shows therefore that the land, which had previously been exposed to wear and decay, was sunk beneath the sea. As the sea advanced over the crystalline rocks it washed over their fragments and deposited them near their source. The currents that sorted the sediments were new and unsettled, so that the deposits were very different in different places and are much more irregular than any later formation.

This formation was much metamorphosed during the folding of the rocks. The alteration is most apparent in the argillaceous beds, where the feldspar has been changed into quartz and muscovite, producing slates and schists. All traces of original bedding are lost where the deposit consisted of only argillaceous matter; in other cases the feldspar developed into quartz and mica plates, lying around the harder minerals. The limestones are recrystallized into marble along the eastern belt only.

Decay penetrates deeply along the slaty layers of the formation, and on them low ground is always formed. Fresh rock is rare, but the siliceous and micaceous parts of the rock break up with extreme slowness, filling the soil and covering the surface of the formation. Weathered ledges are common, consisting usually of the sandstone, and lines of small knolls and hills often accompany the outcrop.

The formation is not important agriculturally, since its areas are not large. Its resultant soils are thin and poor, and as they contain but a small amount of clay they do not retain manures and are too quickly drained.

Weverton sandstone.—This formation is named from its prominent outcrops in South Mountain, near Weverton, Maryland. It consists of massive beds of sandstone and fine conglomerate, with scarcely any beds of finer sediment. It is usually white, and the coarser beds are somewhat gray. Along the Blue Ridge the sandstones are streaked with black and bluish bands. It varies in texture from a fine, pure sandstone, as in Catoctin Mountain, to a fairly coarse conglomerate, as in the southern part of the Blue Ridge.

This rock is composed almost entirely of grains of quartz, with a very little argillaceous matrix. Most of the quartz is white, and similar in appearance to that of the granite and Catoctin schist. In many areas, especially along the Blue Ridge, there are also many blue quartz grains, derived from the blue quartz of the granite. Other materials entering largely into the composition of the sandstone were the iron oxides—magnetite and ilmenite—from the Catoctin schist. Along the Blue Ridge these were sufficiently abundant to produce the dark color and blue streaks in the sandstone.

The fragments in the sandstone are all well worn, and washed quite clean of fine sediment; the particles are also carried to a long distance from their source. The coarseness of some of the fragments and the occasional cross-bedding produced by currents show that much of the formation was a shallow-water deposit along a shore.

The formation varies in thickness much more than in composition. Along the Blue Ridge its thickness is fairly constant at 500–600 feet, so far as known from the incomplete sections. Northward along South Mountain its thickness increases to about 800 feet; also along Catoctin Mountain it increases northward from 100 feet south of

Leesburg to 800 feet toward the northern end of the ridge.

There has been little alteration of the Weverton sandstone. The quartz fragments composing it resisted fracture, and there were few other fragments to break up and form new minerals. What little alteration there is occurs on Catoctin Mountain. This increases southward from a very slight cleavage east of Middletown to marked schistosity west and southwest of Leesburg. Over this range the little feldspar contained in the rock was altered to quartz and mica, and the quartz grains were crushed and cemented again, so that the rock is now composed almost entirely of quartz grains, and splits into slabs whose surfaces are coated with silvery mica.

The Weverton sandstone is not only almost valueless agriculturally but is a decided detriment to the value of neighboring lands. It decays very slowly into a mass of quartz sand with scarcely any clay, so that the cover of soil is thin and is interrupted by frequent ledges. On steep hillsides the sandstone always forms ledges and cliffs, its heavy blocks cover the neighboring slopes, and its smaller fragments choke the streams.

Harpers shale.—This formation occurs in three belts: along the west flank of the Blue Ridge, along the west slope of South Mountain, and on the east side of Catoctin Mountain north of the Potomac. It is so named because of the fine exposures on the Potomac at Harpers Ferry. It is very uniform in texture and composition, and consists of sandy shale with a few sandstone beds in its upper portion. The shales are of a dull bluish-gray color when fresh, and weather to a light greenish-gray. North of the Potomac the upper sandy beds are somewhat more prominent. The shales are composed mainly of argillaceous material, with many small grains of quartz and feldspar. Small grains of epidote and magnetite derived from the Catoctin schist also appear in most specimens under a microscope.

It is difficult to determine the thickness of the Harpers shale, because no complete section of it is known. Its areas are everywhere included between faults which have cut off unknown thicknesses, and the rock is everywhere much twisted and compressed. Its upper portion is seen at the north end of the Blue Ridge, but its lower part does not appear within the area of the sheet except along Catoctin Mountain. Comparison of a number of measurements in other areas has given a probable thickness of 1,200 feet.

Considerable alteration has taken place in the shale in all localities. The feldspathic material has been partially recrystallized into quartz and mica, and schistosity has thus developed. In the Catoctin area of the formation this change has proceeded so far that the rock is composed entirely of quartz and mica, arranged parallel to each other and producing a mica-schist. Between these layers small quartz lenses are also developed.

Soils produced by decay of the Harpers shale are of moderate value. The rock decays to considerable depths, and the argillaceous matter furnishes a sufficient amount of clay. On steep slopes the soil, being light, is easily washed; but elsewhere the quartz and mica particles are about sufficient in amount to secure good drainage. In the Catoctin area the alteration of the rock has produced an excess of insoluble mica and quartz, which fills the soils and makes them of little value.

Antietam sandstone.—This formation is displayed in a series of small areas west of the Blue Ridge and South Mountain. The sandstone is best shown on the tributaries of Antietam Creek, from which it takes its name. Between this formation and the Harpers shale there is a transition, by interbedding of sandstone and shale. The formation is composed entirely of sandstone and is about 500 feet thick, but it has been measured in this area only at the north end of the Blue Ridge. The sandstone is composed of small grains of white quartz, well worn and sorted, and it contains a small percentage of carbonate of lime. Its color is almost invariably white, but some of its upper layers, nearest the Shenandoah limestone, are dull light-brown. It is one of the few formations in this area which contains fossils, chiefly the remains of trilobites.

The sandstone is practically unaltered in all the outcrops along South Mountain and Blue Ridge. East of Catoctin Mountain are some very siliceous schists that may possibly represent the Antietam sandstone in a highly altered condition.

This formation is unimportant agriculturally on account of its small area. In most places it forms deep soils by the solution of its calcareous parts, and outcrops are very rare, but numerous lumps of the sandstone strew the surface. The abundance of these fragments in the soil and the scantiness of the clay render most of its area unavailable for agriculture.

Shenandoah limestone.—The Shenandoah limestone differs strikingly from previously deposited formations, which were largely siliceous and composed of particles of appreciable size. It forms the great Shenandoah Valley, and reaches from New York to Alabama. In general it is a series of blue and gray limestones and dolomites, with occasional beds of mottled blue limestone. Analyses of a large number of moderately pure beds give from 44 per cent to 78 per cent of carbonate of lime, averaging 52 per cent, and from 10 per cent to 42 per cent of carbonate of magnesia, averaging 38 per cent.

The prevailing calcareous character of the formation is locally modified by a series of slates and sandy shales interbedded with the limestone. These are most prominent along the east side of Shenandoah Valley, and in consequence of repeated folding they cover a great deal of the surface. As nearly as can be determined in the complicated folds, this slaty series is about 1,000 feet below the top of the limestone. These beds are best exposed along Antietam Creek, where they become less calcareous and assume a reddish-purple color.

Another exception to the usual character of the formation is a bed of white marble, found at various points around the north end of the Blue Ridge and occasionally along the course of the Shenandoah River. It is pure, and of fine, even grain, but not of sufficient body to be valuable. It probably lies below the slaty limestone series, but its position is obscured by the complicated structure.

Fossils are found in the lower limestones and slaty limestones of this formation, but they are rare. They consist largely of trilobites and lingulæ of Lower Cambrian age. Fossil brachiopods, gasteropods, corals, and crinoids, of Lower Silurian age, are also found in abundance in the upper layers.

The limestone beds have been but little altered since their deposition. Occasionally cleavage is developed on the axis of a fold. The slaty beds are very generally metamorphosed, and the argillaceous material in them has produced mica, causing the slaty cleavage.

The soil of the Shenandoah limestone is a red clay of great depth, and consists of the insoluble matter accumulated after solution. Through this protrude occasional ledges of harder limestone. The Shenandoah limestone, by solution of its lime and magnesium carbonates, decays faster than any of the other formations. The slaty beds are much less easily decayed, and their more sandy and micaceous bits are left scattered through the soils. On account of this feature these latter soils are somewhat better drained than the pure limestone soils. All of them have long been famous for their fertility and excellence in producing any crop suited to the climate.

Martinsburg shale.—This formation occurs only in one belt in this area—near the center of the Shenandoah Valley. Martinsburg, West Virginia, is situated on the western edge of this belt and gives its name to the formation. It consists of black and gray calcareous and argillaceous shales of fine grain, and shows no variations within this area. It contains 80 per cent of argillaceous and siliceous matter, and the remainder is chiefly carbonate of lime. It was therefore originally a calcareous mud. When deposition of this mud began, the altitude of the land was increased, the rivers brought more waste to the sea, and the sea became shallower. Animals living in shoal and muddy waters abounded and left their remains as fossils. These were principally graptolites, corals, brachiopods, and trilobites.

No notable alteration has been produced in the shales except a slight amount of cleavage. This is usually enough to obscure the bedding, which never was sharply marked.

Decay of this formation has proceeded about as fast as in the Shenandoah limestone, being favored by the large proportion of lime in the rock and by the number of shaly partings. The result of decay is a yellow and brown clay soil, of no great depth, which is easily washed away on steep slopes. Drainage is usually good, and the soil is light but not strong

JURATRIAS PERIOD.

Newark formation.—The rocks grouped under this name appear in a wide belt southeast of Catoctin Mountain. They consist for the most part of red and brown sandstone and shale, beds of gray sandstone and conglomerate and limestone conglomerate being present in smaller amount. The red sandstone is composed of grains of sand coated with films of ferruginous clay. The shale is of similar nature and also contains argillaceous matter. Some of the beds are ripple-marked, showing that they formed in shallow water.

The limestone conglomerate is made up of worn pebbles of limestone of various colors, usually blue, interbedded in a reddish, calcareous matrix. Rarely pebbles of slate and gray sandstones also occur with those of limestone. The pebbles were deposited in their matrix in a very irregular manner, and in sharply limited areas. The areas of conglomerate point off into the sandstone like wedges, their form being due either to thinning out away from shore or to subsequent cutting off by faults. From these masses of limestone pebbles it is inferred that a large body of limestone was exposed to erosion and that from its fragments were produced the worn pebbles. The conglomerate being coarse, it was probably laid down by strong currents or waves along a shore, and it is therefore apparently a beach deposit.

Beneath the limestone conglomerate in many places are beds of coarse, gray sandstone. They are largely made up of feldspar, and occasionally—for instance, from 3 to 10 miles south of Leesburg—of pebbles of sandstone, shale, Catoctin schist, and quartz, in a matrix of gray sand. During their formation the land consisted mainly of areas of Catoctin schist and granite, which furnished their fragments to the streams. In these sandstones south of Leesburg carbonaceous fragments and obscure plant impressions are numerous.

Soils derived from these rocks differ widely in value. The limestone conglomerate soils are as good as those of the Shenandoah limestone, and similar to them. They are interrupted by frequent ledges, between which the soil is deep and rich. Usually, however, they are much covered with sandstone wash from Catoctin Mountain. The soils from the calcareous shales are deep and light and very productive, having a good proportion of clay and sand and lying on easy slopes. The red sandstone soils are poorer, on account of the scarcity of clay, but they are of good depth and are not encumbered with ledges or loose rock. The slopes are also easy and give good drainage. Many of their surfaces are strewn with sandstone pebbles from Catoctin Mountain and Blue Ridge. The gray sandstone is of limited extent and does not produce an important soil.

NEOCENE PERIOD.

Lafayette formation.—The Lafayette formation differs from all the older deposits, as it consists of loose gravel and sand, not yet consolidated. Its only occurrence in this region does not show its character at all well, for the deposit has been nearly removed by erosion and is now merely a mass of worn pebbles. The pebbles are mostly sandstone and quartz, the former being derived from the Weverton sandstone of the Blue Ridge and Catoctin Mountain. The Lafayette formation is of little importance in this region, except in indicating that at the time of its deposition the area was sunk below sea-level. It was deposited on a surface worn down to baselevel—part of that which is now conspicuous in the central valley of the mountain district and in the Shenandoah Valley.

STRUCTURE.

Definition of terms.—As the materials forming the rocks of this region were deposited upon the sea bottom, they must originally have extended in nearly horizontal layers. At present, however, the beds are usually not horizontal, but are inclined at various angles, their edges appearing at the surface. The angle at which they are inclined is called the *dip*. A bed which dips beneath the surface may elsewhere be found rising; the fold, or trough, between two such outcrops is called a *syncline*. A stratum rising from one syncline may often be found to bend over and descend into another; the fold, or arch, between two such outcrops is called an *anticline*. Synclines and anticlines side by side form simple folded structure. A synclinal *axis* is a line running lengthwise in the synclinal trough, at every point occupying its lowest part, toward which the rocks dip on either side. An anticlinal axis is a line which occupies at every point the highest portion of the anticlinal arch, and away from which the rocks dip on either side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and is usually but a few degrees. In districts where strata are folded they are also frequently broken across, and the arch is thrust over upon the trough. Such a break is called a *fault*. If the arch is worn and the syncline is buried beneath the overthrust mass, the strata at the surface may all dip in one direction. They then appear to have been deposited in a continuous series. Folds and faults are often of great magnitude, their dimensions being measured by miles, but they also occur on a very small, even a microscopic, scale. In folds and faults of the ordinary type, rocks change their form mainly by motion on the bedding planes. In the more minute dislocations, however, the individual fragments of the rocks are bent, broken, and slipped past each other, causing *cleavage*. Extreme development of these minute dislocations is attended by the growth of new minerals out of the fragments of the old—a process which is called *metamorphism*.

Structure of the Appalachian province.—Three distinct types of structure occur in the Appalachian province, each one prevailing in a separate area corresponding to one of the three geographic divisions. In the plateau region and westward the rocks are generally flat and retain their original composition. In the valley the rocks have been steeply tilted, bent into folds, broken by faults, and to some extent altered into slates. In the mountain district faults and folds are important features of the structure, but cleavage and metamorphism are equally conspicuous.

The folds and faults of the valley region are parallel to each other and to the western shore of the ancient continent. They extend from northeast to southwest, and single structures may be very long. Faults 300 miles long are known, and folds of even greater length occur. The crests of most folds continue at the same height for great distances, so that they present the same formations. Often adjacent folds are nearly equal in height, and the same beds appear and reappear at the surface. Most of the beds dip at angles greater than 10°; frequently the sides of the folds are compressed until they are parallel. Generally the folds are smallest, most numerous, and most closely squeezed in thin-bedded rocks, such as shale and shaly limestone. Perhaps the most striking feature of the folding is the prevalence of southeastward dips. In some sections across the southern portion of the Appalachian Valley scarcely a bed can be found which dips toward the northwest.

Faults were developed in the northwestern sides of synclines, varying in extent and frequency with the changes in the strata. With very few exceptions the fault planes dip toward the southeast, and are parallel to the bedding planes of the adjacent rocks. The fractures extend across beds many thousand feet thick, and sometimes the upper strata are pushed over the lower as far as 6 or 8 miles. There is a progressive change in character of deformation from northeast to southwest, resulting in different types in different places. In southern New York folds and faults are rare and small. Passing through Pennsylvania toward Virginia, folds become more numerous and steeper. In southern Virginia they are closely compressed and often closed, while occasional faults appear. Passing through Virginia into Tennessee, the folds are more and more broken by faults. In the central part of the valley of Tennessee, folds are generally so obscured by faults that the strata form a series of narrow overlapping blocks, all dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

In the Appalachian Mountains the southeastward dips, close folds, and faults that characterize the Great Valley are repeated. The strata are also traversed by the minute breaks of cleavage and metamorphosed by the growth of new minerals. The cleavage planes dip to the east at from

20° to 90°, usually about 60°. This form of alteration is somewhat developed in the valley as slaty cleavage, but in the mountains it becomes important and frequently destroys all other structures. All rocks were subjected to this process, and the final products of the metamorphism of very different rocks are often indistinguishable from one another. Throughout the eastern Appalachian province there is a regular increase of metamorphism toward the southeast, so that a bed quite unaltered at the border of the Great Valley can be traced through greater and greater changes until it has lost every original character.

The structures above described are the result chiefly of compression, which acted in a northwest-southeast direction, at right angles to the trend of the folds and of the cleavage planes. The force of compression became effective early in the Paleozoic era, and reappeared at various epochs up to its culmination, soon after the close of the Carboniferous period.

In addition to this force of compression, the province has been affected by other forces, which acted in a vertical direction and repeatedly raised or depressed its surface. The compressive forces were limited in effect to a narrow zone. Broader in its effect and less intense at any point, the vertical force was felt throughout the province.

Three periods of high land near the sea and three periods of low land are indicated by the character of the Paleozoic sediments. In post-Paleozoic time, also, there have been at least four and probably more periods of decided oscillation of the land, due to the action of vertical force. In most cases the movements have resulted in the warping of the surface, and the greatest uplift has occurred nearly along the line of the Great Valley.

A third type of deformation is found in this area, which does not usually appear in the Appalachian province. Its effects seem to be confined to the Newark rocks, and are such as characterize the Newark areas throughout their extent. During this period of deformation the rocks were tilted at a small angle and were broken here and there by nearly vertical faults. The strata all dip in the same direction, and, on account of their repetition by the faults, appear to have been deposited in a continuous series.

Structure sections.—The sections on the structure sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual dips of the strata are shown. These sections represent the structure as it is inferred from the position of the strata observed at the surface. On the scale of the map they can not represent the minute details of structure, and they are therefore somewhat generalized from the dips observed in a belt a few miles in width along the line of the section.

Faults are represented on the map by a heavy, solid or broken line, and in the section by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have been moved on its opposite sides.

Local structure.—Throughout the area of the Harpers Ferry sheet, folds and faults are numerous, and extend for long distances. Each type of deformation is specially developed in a separate district. In a general way the mountain district marks an uplift exposing the oldest rocks, flanked by the Shenandoah limestone on the west and by the Newark rocks on the east.

Folds occur throughout the region, but they are most prominent and closest in the Shenandoah Valley. The strata dip generally to the southeast, the northwestern limb of the anticline being overturned. A belt of open folds lies immediately west of Blue Ridge and South Mountain, where the compression seems to have been partly taken up in the faults of the mountain district. The close folds of the greater part of the valley are remarkably uniform in height, so that, except in the Martinsburg syncline, the only formation occurring in the valley is the Shenandoah limestone. Examples of the gradual rise and fall of the folds are seen south and east of Martinsburg. The folds of the mountain district are in most cases closed, and often are combined with faults to such an extent as to be obliterated.

Faults occur chiefly along one zone, following the synclinal folds of the Blue Ridge. They follow the rule of development of Appalachian faults in appearing in the northwestern limbs of synclines. The rocks in which they are developed are Cambrian sandstones and shales. These rocks differ widely in strength and pliability, and when they were bent the massive sandstones could not adjust themselves to the close shale folds and accordingly were broken. Narrow fault zones are found in the granite of the central valley where it has been most squeezed and stretched, but this structure differs from the faults of the folded strata in that the dislocation is distributed on many planes instead of being concentrated on one. Except for these zones, the only faults discovered are those in the lower Cambrian rocks. The planes of the faults in the Blue Ridge dip from 10° to 60° to the southeast, the average inclination being about 30°. Along these planes the rocks have been shoved to great distances. In the few places where a limit can be determined the faulting has brought rocks together that were vertically 3,500 feet apart, and the amount of horizontal displacement was much greater. In other places the overthrust can be fairly estimated as from 3 to 5 miles, that being the distance between the ends of the strata which have been broken across.

Metamorphism, the third effect of deformation, is present in the feldspathic rocks of the entire mountain district. In the eastern portion it is especially developed, and invades all formations. The changes due to it have been described under the headings for the individual rocks, and consist in the main of recrystallization of feldspathic material into quartz and mica, with production of schistosity. The metamorphism increases in degree from west to east, and, along Catoctin Mountain, from north to south. Thus, in the sedimentary rocks along the Blue Ridge it is seen only on close inspection, while at the south end of Catoctin Mountain great care is necessary to separate the sedimentary rocks from others. Its prominence in the igneous rocks is due partly to their high percentage of feldspar and their complex chemical nature, and partly to the absence of original bedding planes, along which the rocks could slip without breaking. Along fault planes in particular the development of schist from massive rock can be seen in all its stages. A good instance of this occurs east of South Mountain, at the north edge of the sheet.

Strata of the Newark formation were deposited after the older rocks had been folded and rendered schistose; they therefore did not share in the movements which disturbed and altered those rocks. The Newark beds have nevertheless been dislocated and tilted, and they now dip toward the west at angles varying from 10° to 50°. As this dip is constantly in the same direction for a number of miles, the apparent thickness of the strata is excessive. In other districts a similar appearance is known to be due to faults with a steep dip, which repeatedly bring to the surface strata that have elsewhere dipped underground. The displacement on these faults is in a direction opposite to that on the faults previously described, for the strata east of these faults are depressed, and appear to have been dragged apart instead of compressed. Thus the true thickness of the deposits is greatly exaggerated and can not be determined. In the area within the limits of the Harpers Ferry sheet the existence of these faults can rarely be proved, but it is suggested by the seemingly great thickness of strata and by the manner in which the beds of limestone conglomerate are sharply limited. The fault along the east side of Catoctin Mountain is of this nature, inasmuch as the fault plane dips to the east under the depressed strata. Its dip, however, is less than is usual in faults of this class.

The third general phase of deformation is elevation and depression of the entire region. This is recorded in one manner in the formations already described; it can also be traced in the successive peneplains formed while the land was stationary for a considerable time. Three movements of the former kind and at least four of the latter took place in this region. Of the latter, the most conspicuous at present is marked by the 500-foot peneplain. This also marks the greatest known uplift at any one time,—about 600 feet. The latest uplift, shown in the elevation of the peneplain around Leesburg, is about 300 feet. No warping of the surface during these uplifts can be seen in this region, although in neighboring areas considerable changes were made in this manner. Only one period of depression left any record, during which the Lafayette gravel and sand were deposited, as far west as Catoctin Mountain. Many similar depressions doubtless occurred here, as in other regions, but such movements can not be traced unless the land was covered by water and a deposit formed. Thus the land was subjected to many depressions and uplifts. The latter were in excess, however, and lower and lower rocks came to the surface, to be in turn worn away.

MINERAL RESOURCES.

The rocks of this region are of economic value in many ways, both in the uses to which they are directly put and for the minerals which they contain. Materials of this nature comprise iron ore, ocher, copper, building stone, flags, slates, road stone, clay, lime, cement, and ornamental stones.

Iron ore.—Iron occurs here in one ore, brown hematite. Specular hematite, magnetite, and ilmenite are disseminated through the Catoctin schist, but they do not occur in valuable bodies. The brown hematite is found in two forms of deposit: it accompanies the fault planes which bound the mountain district, and it forms nodules in the residual clay of the Shenandoah limestone. The deposits along the faults were extensively worked and yielded excellent iron in the days of the early charcoal furnaces. The ores are apt to contain much siliceous impurity by inclusion of fragments of Weverton sandstone, and they grade from pure hematite through sandy hematite into ferruginous breccias. The relation of the ore to the fault plane is visible 2 miles north of Leesburg, Virginia, where a thin seam rests on the broken edges of the Weverton sandstone. The ore does not occur in large masses or beds, but has accumulated on the surface and been washed into superficial deposits. The amount of ore is considerable in many places, but it is irregular and uncertain in extent.

The ores of the Shenandoah residual clay are segregated lumps and nodules. In this respect they resemble the ores of the fault planes, but they have no definite arrangement along a structural feature. They occur in the red clay, irregularly scattered in deposits of uncertain lateral extent and of no great depth. They are of good quality and contain from 40 to 60 per cent of iron. These ores are not indicated on the map, as the productive areas are small and widely separated. The total amount of ore from this source is very great, but the fact that it is not in a compact district has prevented any but small mining operations.

Specular hematite is widely distributed over the areas of Catoctin schist, and is often found elsewhere in the wash of streams. In the few places where it has been found in the rock, it forms small deposits with quartz in veins and joints in the schist. An old quarry on Goose Creek, just west of Oatlands, Virginia, shows three sets of joints filled with the vein material. No locality is known, however, where the veins are of sufficient size to warrant mining operations, although the quality of the ore is excellent.

Ocher.—Ocher has recently been found at several points along the eastern base of Catoctin Mountain in connection with the surface wash. The deposits occur beneath the surface of the peneplain at an elevation of about 350 feet. They are usually covered by a bed of gravel and sand from 2 to 8 feet thick, and lie under the bottoms and slopes where the mountain streams deposit their load of sand and gravel. The ocher appears to represent the iron taken in solution from the Catoctin schist and precipitated where it encounters calcareous solutions from the Newark conglomerate.

The ocher thus far prospected is very fine and free from impurities. After the lighter part has been floated off, the small residue consists of grains of magnetite, ferric hydrate, and sand. The particles floated off are ferric hydrate and hydrates of alumina and magnesia. The natural colors of the ocher range from yellow into orange and gray; when mixed with oil they change materially and give a great variety of reds, yellows, browns, and greens.

In the same basins with the ocher, beds of reddle are developed, chiefly in the eastern part of the ocher areas. These are less unctuous than the ocher, but very fine and tenacious. They are reddish-brown, and become darker when mixed with oil.

The amount of the ocher deposits is apparently very great, though they have not been prospected over a wide area. Inasmuch as the streams and bottoms along Catoctin Mountain are similar to those already explored, it seems quite likely that most of them will be found to contain ocher. The depth of the ocher in the larger areas exceeds 30 feet.

Copper.—This metal occurs in the area of the sheet in two forms, native copper and carbonate of copper, or malachite. Native copper is found in many parts of the Catoctin schist throughout Virginia, Maryland, and Pennsylvania. On the Blue Ridge, 2 miles northwest of Paris, Virginia, it occurs associated with malachite, in small seams in the epidotic schist. It has not been discovered in this area in sufficient amount for working. Five miles east of Leesburg, Virginia, malachite is found in the Newark sandstone. It occurs in the form of thin coatings on the surface of the joints and as an impregnation of the mass of the sandstone. Considerable work has been done to develop the ore, and the area in which it occurs is extensive. It is, however, too generally diffused through the sandstone to be available.

Building stone.—Of the various uses to which the rocks of this region have been put, that of building material is most general. Local use has been made of the stone of every formation, where bowlders could be obtained without much labor. This is especially true of the Catoctin schist and granite, whose bowlders of suitable natural shapes are frequent throughout the mountain district. The Shenandoah limestone has furnished much ready-made material for houses and chimneys.

Quarries have been opened for local use in the Newark diabase, the Newark red sandstone, the Shenandoah limestone, and the Catoctin schist. The diabase was opened as "granite" east of Leesburg, and excellent stone was found at the surface. Few natural joints appear, but the rock splits with ease in any direction. Its grain is coarse and uniform, like that of the ordinary granite seen in the markets, but it is rather darker in color. The Shenandoah limestone is admirably adapted for building stone by reason of its numerous bedding surfaces and its softness. It has been quarried for use in dwellings, chimneys, canal locks, and bridge piers. The fact that it is universal in the Shenandoah Valley has prevented the development of an industry in any special place.

The red and brown Newark sandstones have been quarried east of Leesburg and east of Oatlands, Virginia. They are generally known as brownstone. Frequent beds of shale divide the sandstone into layers of moderate thickness, and quarries can readily be opened. Gray Newark sandstone is now quarried immediately east of Point of Rocks, Maryland. These sandstones have been tested by long exposure and do not deteriorate.

Flags and slates.—Along the southern portion of Catoctin Mountain the Catoctin schist furnishes excellent flags. In that region the formation is more metamorphosed and the schistosity more pronounced than elsewhere, so that the rock splits readily into layers of any desirable size. Slates have not been quarried in this region except in a very limited way for ordinary building rock. Certain finer portions of the Loudoun formation southeast of Philomont, Virginia, however, have the purity, hardness, and cleavage necessary in good slate. Along the branches of Goose Creek these could be readily worked in fresh rock with good drainage.

Road metal.—Road metal is procured from many of the formations, chiefly from the Shenandoah limestone. This rock gives the best results, as the stone breaks readily and cements together into a smooth, solid bed. The slates and schists all make smooth and well-drained roads, but are little used. The quartz material from the Catoctin schist is considerably used, and wears well, but it is hard to break and does not cohere. Some roads are built of Weverton sandstone, and are excellent and durable when the rock is broken sufficiently small.

Clay, lime, and cement.—Clays suitable for brick-making are formed from the decay and wash of many of the formations, including the schist, granite, Shenandoah limestone, Newark sandstone, and Newark diabase. Material for the

purpose is so abundant everywhere that bricks are burnt near the point of use, and no special industry has been developed.

Three formations in this area furnish material for lime. At Leesburg the Newark conglomerate has long been burned for lime, and produces an excellent article. The marbles and limestones of the Loudoun formation have been burned near their outcrops for local use, and give pure lime. The Shenandoah beds have long been burned for both lime and cement, principally at Shepherdstown and at a point south of Keedysville, Maryland. Lime of the best quality is obtained from many of the beds, and hydraulic cement is as easily procured. The structure of the Shenandoah limestone is such that beds can be followed for great distances, and the steep dips render open work easy. They thus furnish a practically unlimited quantity of material.

Ornamental stones.—Ornamental stones of great beauty are worked in the Newark conglomerate and Loudoun marbles. Both have been described in this text, each under its respective formation. Conglomerate quarried east of Point of Rocks has been extensively used for interior decoration, under the name of "Potomac marble," and is of great beauty. The Loudoun marbles have not been developed for commercial use, but for beauty and variety they compare favorably with any in the country.

Other ornamental stones are the amygdaloids, jaspers, and epidote lenses of the Catoctin schist. For rich colors and endless variety they are unique, but they are of limited amount, and are available only when weathered out of the schist. They are, moreover, so refractory that it is almost impossible to dress them.

ARTHUR KEITH,
Geologist.

July, 1894.

COLUMNAR SECTION.

GENERALIZED SECTION.
SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
Neocene	Lafayette formation.	Nl			Gravel and sand.	
Juratrias	Newark formation.	Jn	Unconformity	3000±	Conglomerate of limestone pebbles and beds of red shale and sandstone. Red shale and sandstone with diabase dikes. Conglomerate with quartz pebbles.	Low, wide valleys; deep, red, clayey soil. Upland plains and broad, rounded hills; dark-red, sandy soil.
Silurian	Martinsburg shale.	Smb	Unconformity	700–1000	Gray and black shale, calcareous and argillaceous.	Valleys with many small knobs; thin, yellow and brown, clayey soils.
Silurian / Cambrian	Shenandoah limestone.	Ss		2500±	Blue, gray, and dove-colored massive limestone, with bands of slaty limestone and sandy shale.	Broad, flat, and slightly rolling valleys; deep, red, clayey soil.
Cambrian	Antietam sandstone.	Ꞓa		500	Fine, white sandstone with beds of sandy shale.	High, rounded hills and mountains; thin, rocky soil.
Cambrian	Harpers shale.	Ꞓh		800–1200	Gray and bluish-gray, sandy shale, with small beds of gray sandstone.	Knobs and steep slopes. Rolling valleys; yellowish, sandy soil.
Cambrian	Weverton sandstone.	Ꞓw		100–900	Massive, gray and white sandstone and conglomerate of quartz pebbles.	High mountains and lines of high peaks.
Cambrian	Loudoun formation.	Ꞓl		0–800	Argillaceous slate, sandy shale, gray sandstone, quartz conglomerate, blue limestone, and white marble.	Depressions and valleys with little ridges; thin, micaceous, and sandy soil.
Algonkian	Catoctin schist.	Ac	Unconformity	1000+	Grayish-blue and greenish-blue altered diabase, with lenses of epidote and quartz and masses of eruptive granite.	High domes and mountains with broad, arching tops; micaceous, red, clayey soils with many epidote bowlders. Broad, rolling valleys over granite and schist; micaceous and sandy, brown soils and red, clayey soils.

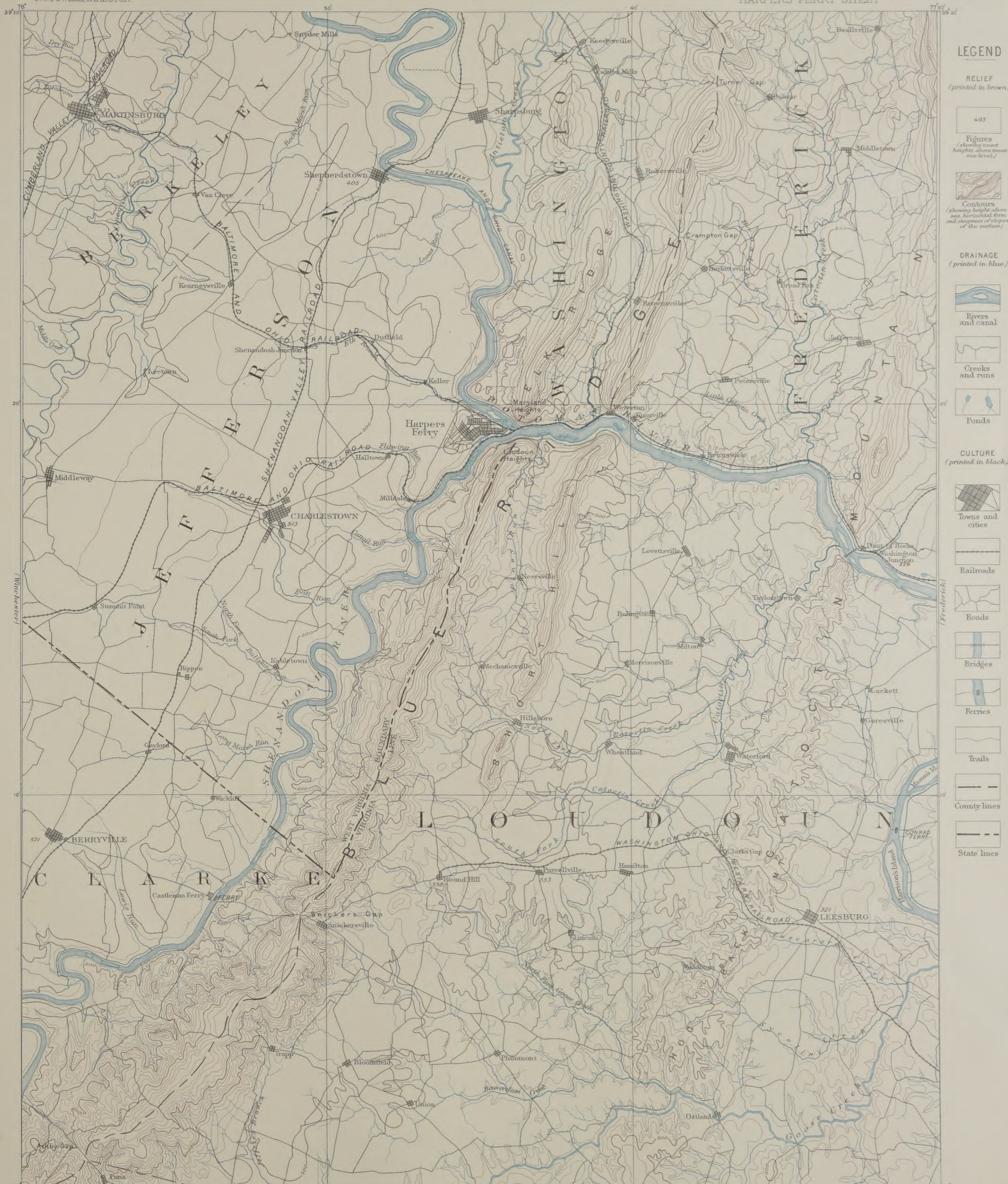
NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		J. M. Safford, Geol. of Tennessee.	W. B. Rogers, Geol. of Virginia.	J. P. Lesley, Geol. Survey of Penn.
Neocene	Lafayette formation.	Nl			
Juratrias	Newark diabase. Newark conglomerate. Newark sandstone.	Jd Jnc Jn		Jurasso-Triassic. Middle Secondary sandstones and coal measures.	Trias.
Silurian	Martinsburg shale.	Smb	Nashville shale.	III. Hudson River. Utica.	III. Utica. Hudson River.
Silurian	Shenandoah limestone.	Ss	Knox dolomite.	II. Trenton. Chazy. Levis. Calciferous.	II. Trenton. Chazy. Calciferous.
Cambrian	Antietam sandstone. Harpers shale. Weverton sandstone. Loudoun formation.	Ꞓa Ꞓh Ꞓw Ꞓl	Chilhowee sandstone.	I. Potsdam.	I. Potsdam.
Algonkian	Schist and granite. Catoctin schist.	Acg Ac		Archean.	Chloritic series.

U.S. GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR.

TOPOGRAPHY

VIRGINIA-WEST-VIRGINIA-MARYLAND
HARPERS FERRY SHEET



Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in charge.
Triangulation by the U.S. Coast & Geodetic Survey.
Topography by the U.S. Coast & Geodetic Survey & W. T. Griswold.

Surveyed in 1884

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet

Edition of July 1893

U.S. GEOLOGICAL SURVEY
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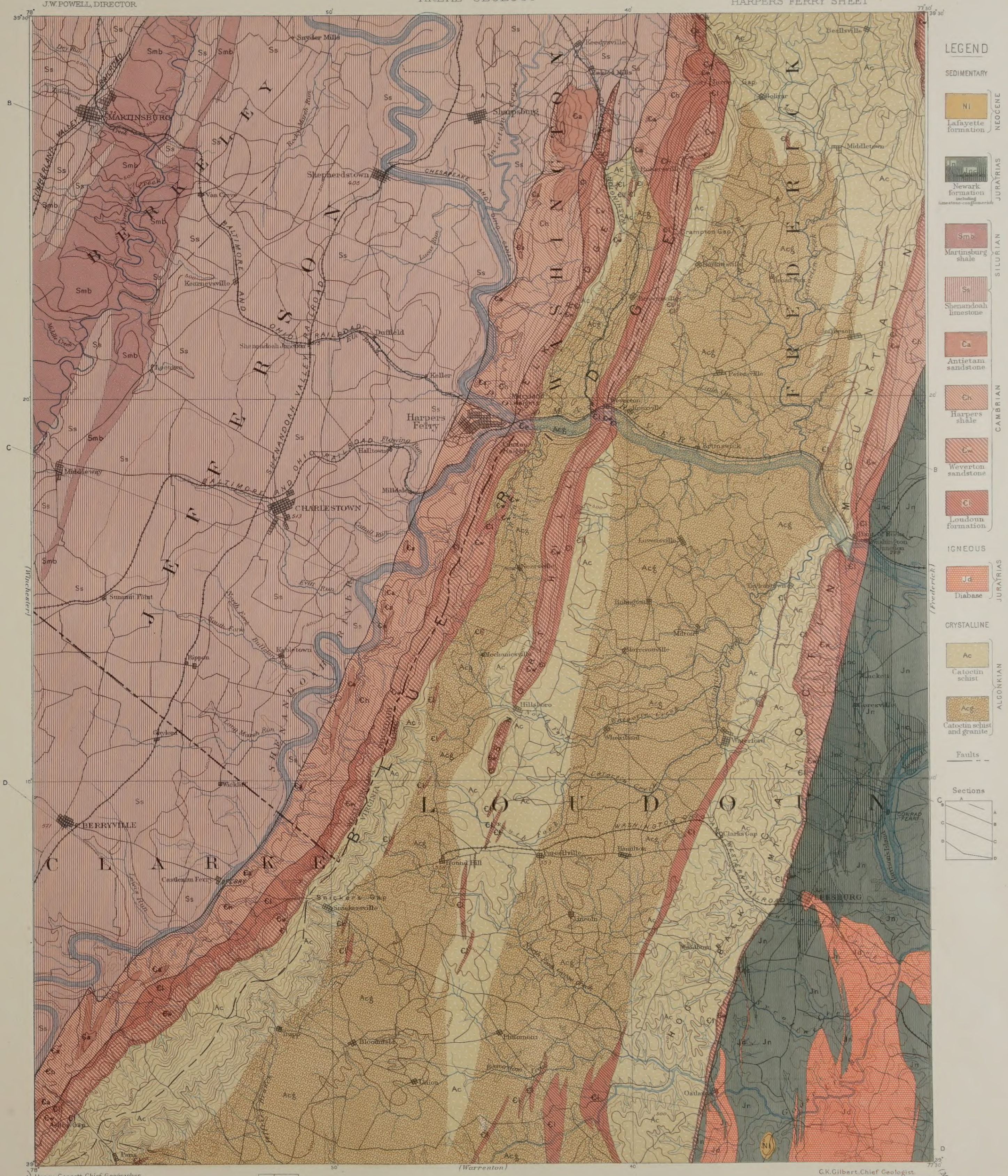
AREAL GEOLOGY

VIRGINIA-WEST-VIRGINIA-MARYLAND
HARPERS FERRY SHEET



Henry Gannett, Chief Geographer.
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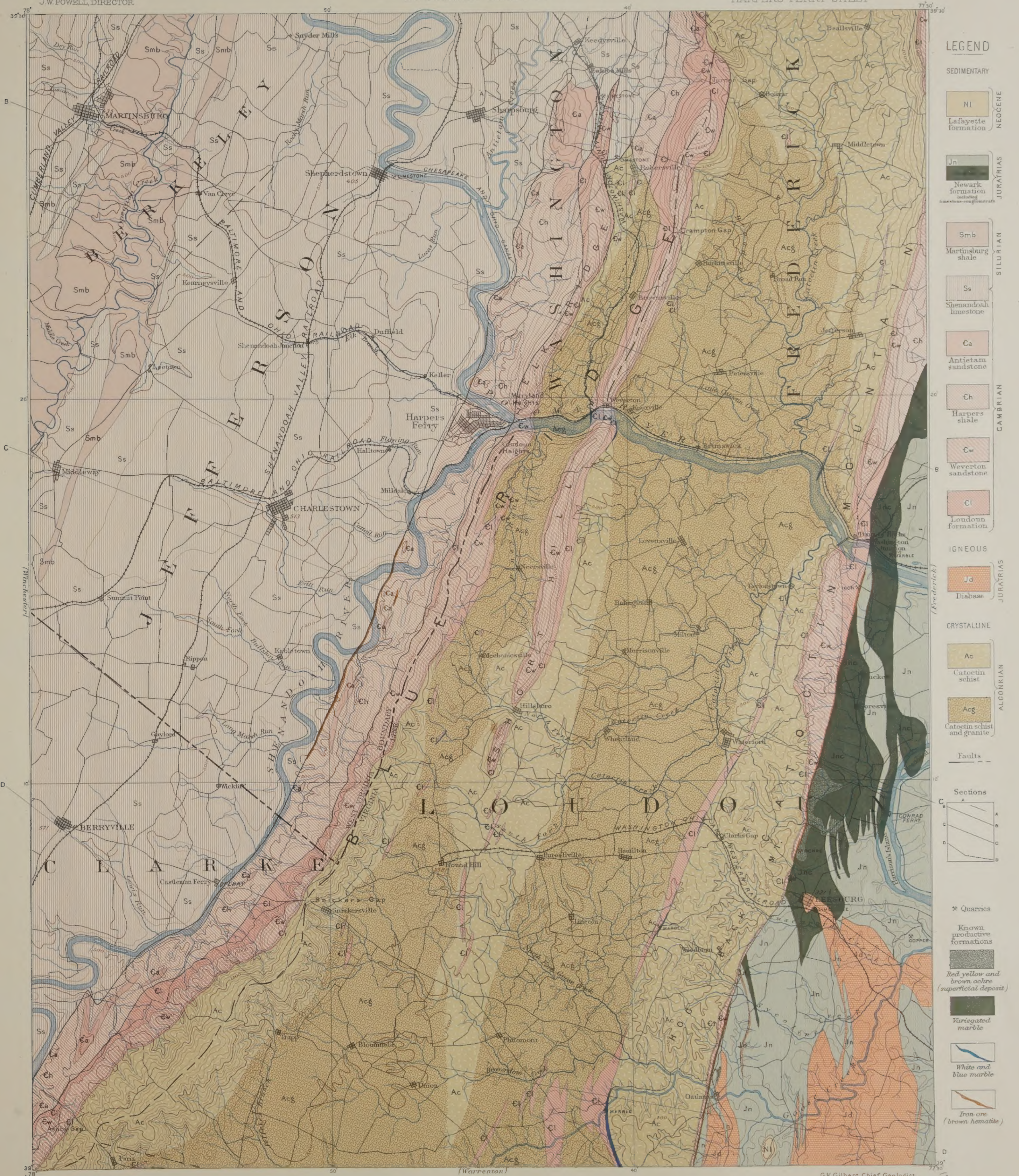
U.S.C. & G.S.
Griswold

Scale $\frac{1}{125,000}$
0 1 2 3 4 5 6 Miles
Contour Interval 100 feet
Edition of July 1893.

G.K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in Charge.
Geology by Arthur Keith.
Surveyed in 1890 & 1891.

ECONOMIC GEOLOGY

VIRGINIA-WEST-VIRGINIA-MARYLAND
HARPERS FERRY SHEET



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Scale 1/125,000

Contour Interval 100 feet
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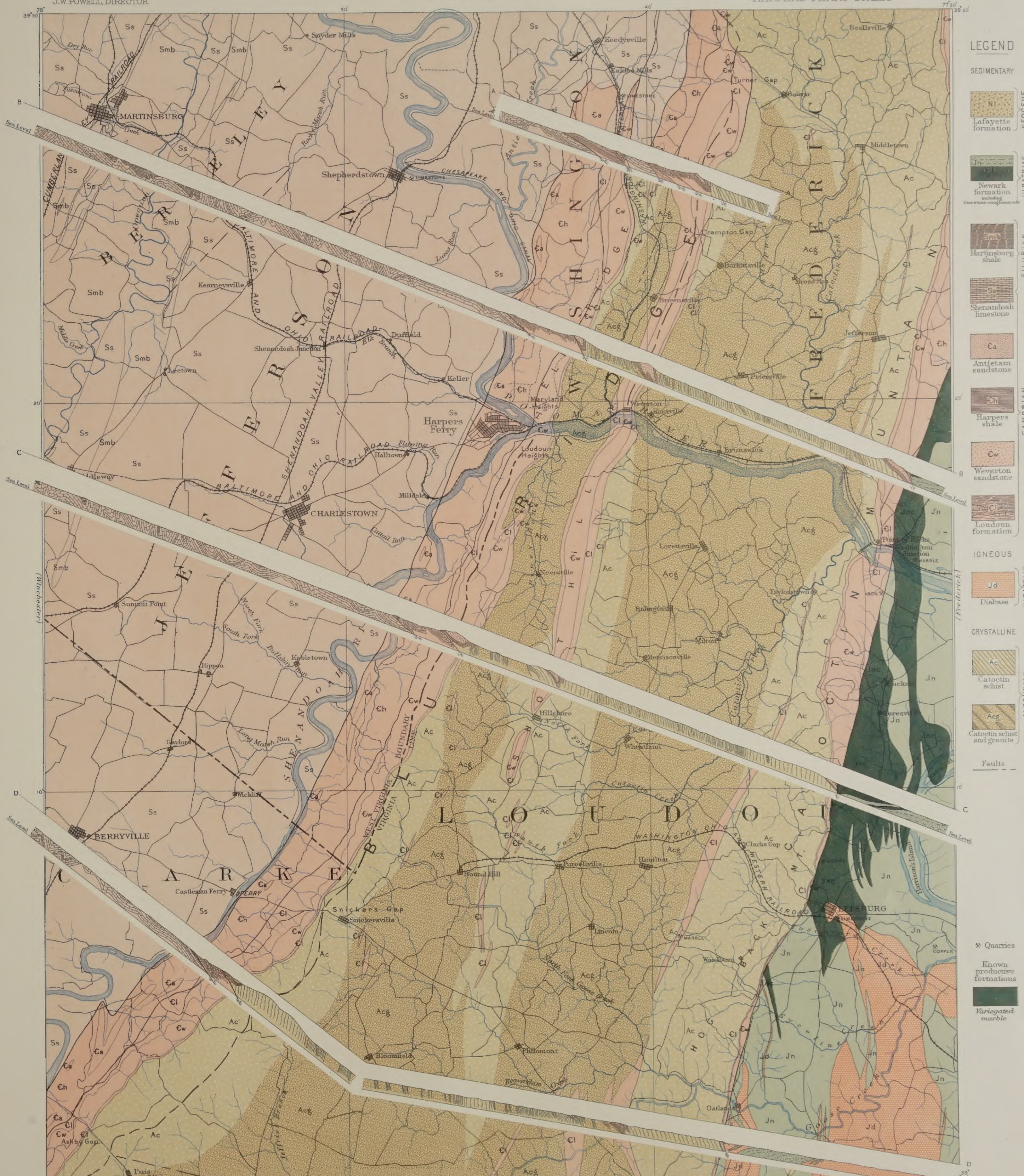
STRUCTURE SECTIONS

VIRGINIA-WEST-VIRGINIA-MARYLAND
HARPERS FERRY SHEET



Henry Gannett, Chief Geographer.
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Surveyed in 1884

Scale 1/125,000
Miles

Contour Interval 100 feet

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pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

It is thought that the first rocks of the earth, which formed during what is called the Archean period, were igneous. Igneous rocks have intruded among masses beneath the surface and have been thrown out from volcanoes at all periods of the earth's development. These rocks occur therefore with sedimentary formations of all periods, and their ages can sometimes be determined by the ages of the sediments with which they are associated.

Igneous formations are represented on the geologic maps by patterns of triangles or rhombs printed in any brilliant color. When the age of a formation is not known the letter-symbol consists of small letters which suggest the name of the rocks; when the age is known the letter-symbol has the initial letter of the appropriate period prefixed to it.

(4) *Altered rocks of crystalline texture.*—These are rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized.

Both sedimentary and igneous rocks may change their character by the growth of crystals and the gradual development of new minerals from the original particles. Marble is limestone which has thus been crystallized. Mica is one of the common minerals which may thus grow. By this chemical alteration sedimentary rocks become crystalline, and igneous rocks change their composition to a greater or less extent. The process is called *metamorphism* and the resulting rocks are said to be metamorphic. Metamorphism is promoted by pressure, high temperature and water. When a mass of rock, under these conditions, is squeezed during movements in the earth's crust, it may divide into many very thin parallel layers. When sedimentary rocks are formed in thin layers by deposition they are called *shales*; but when rocks of any class are found in thin layers that are due to pressure they are called *slates*. When the cause of the thin layers of metamorphic rocks is not known, or is not simple, the rocks are called *schists*, a term which applies to both shaly and slaty structures.

Rocks of any period of the earth's history, from the Neocene back to the Algonkian, may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known remain in some localities essentially unchanged.

Metamorphic crystalline formations are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines.

If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters only.

USES OF THE MAPS.

Topography.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage and culture of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable.

It may guide the traveler, who can determine in advance or follow continuously on the map his route along strange highways and byways.

It may serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold.

It may save the engineer preliminary surveys in locating roads, railways and irrigation ditches.

It provides educational material for schools and homes, and serves all the purposes of a map for local reference.

Areal geology.—This sheet shows the areas occupied by the various rocks of the district. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern on the map the reader should look for that color and pattern in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its colored pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

The legend may also contain descriptions of formations or of groups of formations, statements of the occurrence of useful minerals, and qualifications of doubtful conclusions.

The sheet presents the facts of historical geology in strong colors with marked distinctions, and is adapted to use as a wall map as well as to closer study.

Economic geology.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors.

A symbol for mines is introduced in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

Structure sections.—This sheet exhibits the relations existing beneath the surface among the formations whose distribution on the surface is represented in the map of areal geology.

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial cutting which exhibits those relations is called a *section*, and the same name is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

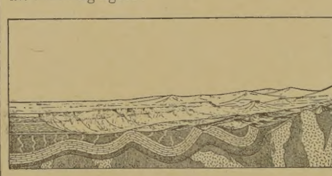

Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows the underground relations of the rocks. The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

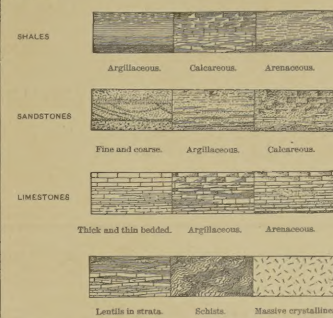

Fig. 3. Symbols used to represent different kinds of rocks.

The plateau in Fig. 2 presents toward the lower land an escarpment which is made up of cliffs and steep slopes. These elements of the plateau-front correspond to horizontal beds of sandstone and sandy shale shown in the section at the extreme left, the sandstones forming the cliffs, the shales constituting the slopes.

The broad belt of lower land is traversed by several ridges, which, where they are cut off by the section, are seen to correspond to outcrops of sandstone that rise to the surface. The upturned edges of these harder beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

Where the edges of the strata appear at the surface their thicknesses can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

When strata which are thus inclined are traced underground in mining or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales and limestones were deposited beneath the sea in nearly flat sheets. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

The mountain peaks on the right of the sketch are shown in the section to be composed of schists which are traversed by masses of igneous rock. The schists are much contorted and cut up by the intruded dikes. Their thickness cannot be measured; their arrangement underground cannot be inferred. Hence that portion of the section which shows the structure of the schists and igneous rocks beneath the surface delineates what may be true, but is not known by observation.

Structure sections afford a means of graphic statement of certain events of geologic history which are recorded in the relations of groups of formations. In Fig. 2 there are three groups of formations, which are distinguished by their subterranean relations.

The first of these, seen at the left of the section, is the group of sandstones and shales, which lie in a horizontal position. These sedimentary strata, which accumulated beneath water, are in themselves evidence that a sea once extended over their expanse. They are now high above the sea, forming a plateau, and their change of elevation shows that that portion of the earth's mass on which they rest swelled upward from a lower to a higher level. The strata of this group are parallel, a relation which is called *conformable*.

The second group of formations consists of strata which form arches and troughs. These strata were continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first group, being parallel, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second group on the left of the section. The overlying deposits are, from their position, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata or upon their upturned and eroded edges, the relation between the two is *unconformable*, and their surface of contact is an *unconformity*.

The third group of formations consist of crystalline schists and igneous rocks. At some period of their history the schists have been plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second group. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of strata of the second group. During this interval the schists suffered metamorphism and were the scene of eruptive activity. The contact between the second and third groups, marking an interval between two periods of rock formation, is an unconformity.

The section and landscape in Fig. 2 are hypothetical, but they illustrate only relations which actually occur. The sections in the Structure Section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond to the actual slopes of the ground along the section line, and the depth of any mineral-producing or water-bearing stratum which appears in the section may be measured from the surface by using the scale of the map.

Columnar sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

The characters of the rocks are described under the corresponding heading, and they are indicated in the columnar diagrams by appropriate symbols, such as are used in the structure sections.

The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest thicknesses. The average thickness of each formation is shown in the column, which is drawn to a scale,—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement of the descriptions and of the lithologic symbols in the diagram The oldest formation is placed at the bottom of the column, the youngest at the top. The strata are drawn in a horizontal position, as they were deposited, and igneous rocks or other formations which are associated with any particular stratum are indicated in their proper relations.

The strata are divided into groups, which correspond with the great periods of geologic history. Thus the ages of the rocks are shown and also the total thickness of deposits representing any geologic period.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied, not only by the description of its character, but by its name, its letter-symbol as used in the maps and their legends, and a concise account of the topographic features, soils, or other facts related to it.

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Director.